Simultaneous Generation and Enhancement of THG and SHG in a Stable Microfibre Knot Resonator

R. Ismaeel[1], **T. Lee**[1], **G. Brambilla**[1]
1. Optoelectronics Research Centre, University of Southampton, Southampton, Hampshire, SO17 1BJ, United Kingdom

Third harmonic generation (THG) in microfibres can be efficiently generated by phase matching the fundamental mode at the pump wavelength with a high order mode at the third harmonic (TH) wavelength at specific microfibre diameters [1]. Similarly, second harmonic generation (SHG) arising from the lack of centrosymmetry at the microfiber surface as well as higher order bulk effects [2], can be optimised by appropriate intermodal phase matching. Pump power recirculation in a microfibre loop has been proposed as method to improve the THG efficiency [3], as attempts to generate SH and TH in microfibres have shown relatively low efficiency. Yet, the loop mechanical instability remains an issue. Here, we report on using a microknot resonator to recirculate pump light and enhance THG and SHG with high stability and reliability. A strong efficiency enhancement is observed, possibly due to an improved pump coupling in the knot resonator.

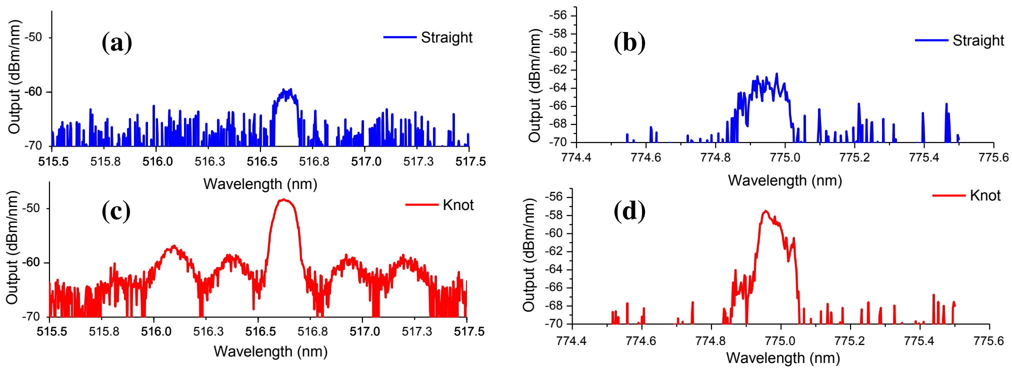

Figure 1: Generated third (a) and second harmonics (b) in straight microfibres. A 13.8dB enhancement was recorded for the THG (c) and 6.6dB for the SHG (d) when the microfibre was configured into a knot resonator.

To experimentally demonstrate harmonic generation in the knot resonator, a 15 mm long microfibre of 700 nm diameter (chosen to phase match the fundamental pump $HE_{11}(\omega)$ with the harmonic mode $HE_{12}(3\omega)$) was manufactured using the modified flame brushing technique, whilst pumped with 4 ns pulses at $\lambda = 1550$ nm, 250kHz and peak power of 100 W from a tunable source. The microfibre output was monitored on a spectrum analyser to observe the harmonic signal during fabrication. Before tapering, a large knot was created using the fibre pigtails to ease manufacturing of the microknot later. Tapering was stopped when the third harmonic was observed. The resulting THG and SHG spectra for the straight microfibre are reported in Fig. 1(a) and (b) and reveal efficiencies of $\eta_{3\omega} = 1.4\times10^{-5}$ and $\eta_{2\omega} = 1.69\times10^{-6}$, respectively. The microfibre knot was fabricated using two motorised stages to optimise the knot position in the microfibre region. Pulling was stopped when a strong harmonic signal enhancement was observed, corresponding to a knot diameter of 1.3mm and a resonant extinction ratio of 7.3dB at $\lambda = 1.55\mu$m.

Fig. 1(c) and (d) show the THG and SHG signals from the knot output, with enhancements of 13.8 dB ($\eta'_{3\omega} = 3.7\times10^{-4}$) and 6.6 dB ($\eta'_{2\omega} = 7.56\times10^{-6}$), respectively. As expected, the enhancement for THG is higher than for SHG, since the TH power scales cubically with the pump power (rather than quadratically, as for SHG). This THG enhancement is over four-fold greater than that previously reported in the loop [3]. Note that the knot has been optimised for THG, and higher SHG efficiencies – up to 2.3×10^{-5} – were in fact recorded during the optimization process. By increasing the pump power, the THG efficiency could be further increased up to 2.7×10^{-3}. Mechanically, the knot was confirmed to be extremely robust, providing very stable and consistent output spectra.

References

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